THE GRAPE-BERRY WORM

Polychrosis viteana Clemens

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BULLETIN
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THE GRAPE-BERRY WORM (*Polychrosis viteana* Clemens)

W. H. GOODWIN

HISTORICAL

The grape-berry worm, *P. viteana* Clemens, is a native insect the economic importance of which was first noted in 1860 by Dr. Clemens, who named it and gave a brief description of some of its habits. It has been unusually destructive at various times in New York, Pennsylvania and Ohio, in those sections where grapes are the predominating crop. It has been a serious pest in some other states, but has never become a menace to the grape industry as it has in the grape-producing sections of the three states named.

The original food plant seems to have been the wild grapes which, at one time, were abundant from the Alleghenies west to Nebraska, and south to Arkansas, Oklahoma and Texas. The change to living on the domesticated varieties of grapes came with the planting of large areas to vineyards, thus producing favorable conditions for the development of the berry worms. The larvae of *Polychrosis viteana* have often been found feeding in the clusters of wild grapes; and, as the species is confined in its range to North America, there can be no doubt that it is a native species which has become a pest through the reduction in numbers of its original food plant, or because it has found in the cultivated grape a food more to its liking.

The regions suffering most seriously from its depredations are near the shores of Lake Erie, where the crop of grapes is seldom destroyed by frost during the blossoming period or later. When the grapes are blooming, frost often destroys most of the crop in central and eastern Ohio, leaving practically no grapes upon which the berry worms can live. This condition naturally controls the

berry worm in these sections, as the crop is destroyed as often as once every 4 to 6 years, leaving but little opportunity for this insect to become a serious pest during the intervening years of plenty.

Letters of inquiry concerning its injuries have been received from Dayton, Columbus, Springfield, Toledo, Canton, Newark and a number of other points in Ohio where the grapes in arbors or vineyards are attacked. In the vicinity of Wooster most of the wild grapes found in October are always wormy, and in many grape arbors the berries are exceptionally wormy in some years but are practically uninjured in other years. The wild-grape berries have been injured by the berry worm in some localities the year following the complete destruction of the domesticated grape crop by frost. It is puzzling how these berry worms can be so plentiful in the year following no crop, unless the moths are able to fly long distances or breed on a very few wild grapes in some protected situation.

During 1908 and 1909, the berry worm almost disappeared from some localities in the region of Marblehead, and on the islands in that vicinity its injuries decreased noticeably. It was plentiful just east of Cleveland in 1908, but had decreased quite perceptibly in 1909, and in 1910 it did not seriously damage the crop in this region. In 1912 and 1913, the injury east and west of Cleveland was very severe, and in 1914, although the crop was heavy, the larger part of it was seriously injured. The 1915 grape crop was undoubtedly more seriously injured by berry worm than that of any recent year.

In 1870, or 10 years after being described by Dr. Clemens, some specimens of the berry moth were sent to Zeller, a European specialist, who pronounced them identical with the European species, *Polychrosis botrana* Schiff. Although differing in habits from *botrana*, its species identity was not questioned again until Prof. M. V. Slingerland began his studies of the insect, and in 1904 published a record of its life history and habits. He found that the life history of the American species differed greatly from that of the European moth. Some of these differences had been recorded previously; yet the systematist in classifying this insect ignored or was unacquainted with the record of its differing habits and life history. At the solicitation of Prof. Slingerland, W. D. Kearfott monographed this genus of tortricids in 1904, and gave the distinguishing characters of the berry moth as well as those of a number of closely related species, referring it back to the name given by Clemens in 1860—*Polychrosis viteana*.

Riley gives an account of its ravages in Illinois and Missouri in 1868 and 1869. At this time, it was noted that the larva pupated in a fold, or flap, of the leaf by drawing a section of the leaf over itself and by spinning a silken cocoon inside. According to European entomologists, *Polychrosis botrana* pupates in the fall on posts, trellises or rough vines and never in a fold or pocket of the leaf.

Saunders gave a brief account of *Polychrosis viteana* in his Ontario report in 1882. Felt (1904) reported the first beneficial work from spraying with arsenicals. In some experiments for the control of the grape fidia (*Fidia viticida*), beneficial effects were obtained as well with the berry worm, it being partly controlled. *Polychrosis viteana* was reported as injurious in the vineyards of Ohio in 1869, and again in 1881 it did considerable injury to grapes on the islands in Lake Erie. At various times it has been reported from New York, Pennsylvania, Ilinois, Ohio, Missouri, Delaware, Virginia, North Carolina, Texas, Nebraska and Ontario.

DESCRIPTION

Adult.—The adult is a small moth, lilaceous and brown in color, and measures from 9 to 12 millimeters (⅓ to ½ inch) across its expanded wings. When viewed from above, the moth at rest is triangular in appearance and is scarcely 6 millimeters long and not more than 2½ to 3 millimeters broad. It takes flight at the slightest disturbance, is a rapid flyer and crawls rapidly about the breeding jar when disturbed. Kearfott describes the moth as follows: "Front wing; ground color lilaceous or leaden blue. The outer marginal patch is sharply indented above the anal angle by a spur of the ground color; the inner edge is less straight than *botrana* and bulges inward at the middle of wing; the color is dark brown. The central fascia is narrower than *botrana* and the two short inner dorsal fasia are only indicated by a few brown scales. Apical spot is larger than *botrana* and there are three smaller rectangular oblique spots on costa beyond the central fascia. The inner spot, which in *botrana* is as distinctly defined as the other four, is in *viteana* not separable from central fascia. A few short streaks on costa before the middle. A shade of pale yellowish-brown involves the outer half of costa between the central fascia and outer patch, giving the outer half of wing this color. Hind wing smoky-brown becoming paler at base. Expanse 10 to 11.5 millimeters."

Few American collections contain specimens of *botrana* for comparison with *viteana,* and hence Riley's description will be more valuable to the average student: "Perfect insect: Average length 0.17″; alar expanse, 0.37″. Head, thorax, palpi and basal half of antennae fulvous. Terminal half of antennae darker. Legs fulvous, becoming darker on tarsi. Ground color of forewings, pale slate-blue with slight metallic luster which becomes lighter and somewhat silvery anteriorly and posteriorly. A dark, rich brown band, with a light, somewhat silvery annulation, proceeds from the middle of the costa towards the inner margin, becoming paler anteriorly; its basal margin being indistinct but running almost straight across the wing, its outer margin well defined, curving to a rounded point which reaches to the middle of the outer third of the wing and thence running obliquely inwards nearly to the middle of the inner margin. Beyond this middle band is a large, deep brown, somewhat oval spot, also lighter below than above and with a pale annulation, which is broken on the outer-side above, allowing the spot to extend to the margin of the wing. Above this large spot at the apex is a small, perfectly round dark spot, with a bright annulation inclining to orange color. The space inclosed by the middle band and these two spots just described, is brown above with usually four lighter fulvous costal marks, quite distinct, each mark divided at costa by a slight touch of brown. Another somewhat triangular brown spot with a light annulation above, runs from the posterior angle up between the middle band and a large oval spot. The blue space from the middle band to the base of wing is generally brownish near base, with a brown line across the middle from costa to inner margin, and with two other costal brown marks. The fringes partake of the ground color. Hind wings slate brown, darkest near margin; fringes same color. Body brownish with frequently a clear green tint. The male differs principally in its somewhat smaller size, and especially in the smaller size of the abdomen. Individuals vary greatly.

Larva.—"Larva—average length 0.35 inch. Largest on segments ten and eleven, tapering thence gradually to the head, and suddenly to the anus. Color either dark, shiny, olive green, glaucus or brownish. Head and cervical shield honey-yellow, the latter with a darker posterior margin. Piliferous spots scarcely distinguishable. Described from ten specimens.

Chrysalis.—"Chrysalis, 0.18-0.20 inch long. Of normal form. Quite variable in color. Usually of light honey-yellow, with a green shade on the abdomen, and black eyes, but sometimes entirely dark

green with light eyes. The chrysalis skin, after the moth has left, is always deep honey-yellow, with the green abdominal mark distinct."

Egg.—The eggs are thin, semitransparent, with a finely reticulated surface, and are oval in outline. Slingerland describes them thus: "The thin, rounded, scalelike, semitransparent eggs, measure 0.6 to 0.8 by 0.7 to 0.9 of a millimeter in size and appear whitish in a few days. The shell is finely reticulated and the egg appears to be glued to the fruit by some substance. The eggs look much like the codling-moth egg, only smaller." The eggs are oval in outline with a strongly curved upper surface yellowish or grayish white in color, becoming pure white after hatching.

LIFE HISTORY AND HABITS

First brood.—In northern Ohio the adult *Polychrosis viteana* normally emerges from its winter cocoon during the first or second week in June to about the first week in July. Winter has been passed in the pupal stage in a cocoon spun inside a fold made in a grape leaf during the previous fall. The cocoons are usually found on leaves stuck in the wet soil or partly covered with mud, and rarely, if ever, are found in the piles of leaves, or in trash into which leaves have been drifted by the wind. A few days after emerging, the moths deposit their eggs on the buds and stems and on the newly formed berries of the grape bunches. The eggs hatch in from 4 to 8 days, and the larvae feed on the tender stems and developing berries of the grape cluster. Sometimes the work of the larvae is fairly conspicuous at this season of the year, as the entire cluster is often webbed together by delicate, white, silken threads which are spun around part of the young grape bunch. These cannot be readily found every year, as many larvae do not spin a noticeable amount of web. Inside this web the larva lives, devouring the flower buds, stems and young berries, often almost destroying the young grape cluster. The idea that the berry worm might have another host plant at this season of the year has been suggested by the size of the brood later in the season, but this is an impossibility because there is often no other host plant excepting grapes in many of the worst infested localities. All the author's attempts to rear it on other food plants have resulted in failure.

The injury by the second brood of the European berry moth is partly prevented by going through vineyards when the first brood of worms is attacking the newly formed clusters, and crushing the larvae in each of the webbed clusters of grapes. This method is

not practical in Ohio, as some larvae of *P. viteana* do not spin much silk, and hence are hard to find. The brood is scattered and would require careful picking at least three or four times. The price of labor and lack of trained workers would make the cost prohibitive.

The larvae of this brood develop rapidly, the larger part of them being full-grown in 20 to 27 days after hatching. A few stragglers may require as long as 34 days to complete their development. When the berries are about one-eighth inch in diameter or larger, the later-hatching worms bore into the berries. The berry is growing rapidly; and, as a result of destroying the growing tissue just beneath the skin and thus preventing growth around the puncture, the berry splits open. In some localities, this injury has been attributed to the grape rots, when the real trouble was the late-hatching, first-brood larvae of the grape-berry worm, which had created ideal conditions for the growth of rot fungi through the injury done to the berries. When mature, the first-brood worms migrate from the bunches of injured grapes to young, tender grape leaves, where the worm draws the edge of the leaf over itself by silken threads attached to the surface and edge of the leaf. This forms a fold, or tube, inside which the worm spins a white, silken cocoon and pupates within 2 or 3 days. In from 7 to 10 days the pupa pushes itself almost out of the cocoon, splits open at the anterior end and along the back for almost half its length, and the moth of the August brood appears.

Second brood.—The normal date of emergence of a large part of the brood of moths is from the 5th to the 12th of August in northern Ohio (see life history chart), but varies slightly with the season. These moths lay their eggs on the grape berries. A few of the eggs are laid on the stems where these swell to meet the berries. The berries are almost grown, and at this season of the year, with normal weather conditions, the eggs of the berry moth hatch in 3 to 6 days after being laid. The tiny larva bores through the skin of the grape and feeds just beneath on the cells of the developing berry.

These second-brood larvae, boring into the almost full-grown grape berries, cut off in part the supply of nourishment to the cells above the injured portion, causing premature ripening; and the purplish or reddish-purple spot surrounding the point of entrance soon appears, often extending over one side of the berry. This is the typical injury noted by Riley in his Missouri reports, and in northern Ohio is caused by the second brood of larvae. Riley describes it as follows: "Its presence is soon indicated by a reddish-brown color on that side of the yet green grape which it enters.

On opening the grape a winding channel is seen in the pulp, and a minute white worm with a dark head is seen at the end of the channel. It continues to feed upon the pulp of the fruit, and when it reaches the seeds, eats out their interior. As it matures, it becomes darker, being either of an olive green or dark brown color, with a honey-yellow head, and if one grape is not sufficient, it fastens the already ruined grape to an adjoining one by means of silken threads, and proceeds to burrow in it as it did in the first. When full-grown, it leaves the grape and forms its cocoon on the leaves of the vine. This operation is performed in a manner essentially characteristic; the worms cut out a clean oval flap, leaving it hinged on one side, and, rolling this flap over, fastens it to the leaf, thus forming for itself a cozy little house which it lines on the inside with silk. In this cocoon within two days it changes to a chrysalis of a honey-yellow color of a green shade on the abdomen."

The second-brood larvae have a tendency to leave the berries in which they are working and to attack other berries which are close to those in which they have been feeding, leaving each berry as soon as it begins to ferment, or the contents evaporate. They spin a silken covering between the berries, attaching each newly attacked berry to the preceding one in which they were feeding. In this way, as many as five to seven berries may be destroyed by one worm of the second, or August, brood. The juice in the injured berries evaporates, and frequently a bunch of Concord grapes has half or more of the grapes dried out with only the black dried skins remaining and looking almost like sound grapes. In many vineyards, fully half of the berries in a cluster of grapes are only shells by the 10th of October.

Some larvae of this brood are not mature until late in October, and they are often active after the occurrence of some severe frosts. The earlier maturing larvae spin their cocoons before many of the leaves fall. They drop to the ground, or let themselves down by silken threads, rarely falling with the berries in which they are feeding. These larvae then seek some leaf anchored in the soil or lodged in the mud, cut the tiny flap, pulling it over by means of silken threads, forming a small, podlike sheath lined with a thin, white silken cocoon, and inside this protecting cocoon, the larvae transform into pupae.

Habits of larvae.—The habits of the larvae are distinctive and characteristic only of this insect. The dark olive-greenish to bluish-black larvae are very active when disturbed. The second-brood larvae wriggle out of a bunch, if disturbed, and by means of a silken thread lower themselves rapidly to the ground. When

found in a berry, they will often crawl out and escape capture. The larva of the first brood, in spinning its cocoon, usually draws over the edge of a young tender leaf and makes a fold, or pocket, inside which it spins its cocoon. Just as often, the second-brood larvae cut a flap out of the central part of a leaf, but they spin cocoons upon the moist leaves on the ground and never upon green leaves on the vine. These cocoons readily break out and away from the dried leaf during the fall or winter and lay on the ground until the pupae transform into moths in the following June or July.

In no case could the larvae be induced to spin cocoons upon grass or leaves other than those of the grape, when these were introduced into the breeding cages, but a few spun upon moist newspaper. It would seem that the berry-moth larvae would spin cocoons upon leaves of similar texture to grape leaves if other conditions were similar. Some larvae transformed into pupae without spinning a cocoon of any kind, and a few died without attempting to spin cocoons or transforming to pupae.

Flight.—The small, lilaceous, brown moths are inconspicuous when at rest upon the bark of a grapevine or upon dead wood. When disturbed, they fly with a rapid motion of the wings, with a peculiar zigzagging flight which makes them exceptionally hard to follow. They fly low, and are most active from 3.00 p. m. until dusk. They are active during the night, but it is impossible to watch them in indoor breeding cages unless a strong artificial light is used. Observations in outdoor breeding cages can sometimes be made if a small electric searchlight is used, but under the stimulus of strong artificial light the moths become excited, and their actions are abnormal. Lanterns of the ordinary kind do not attract the moths at night and have proved unsuccessful as lures to traps. The larger lights may prove to be good lures, but this is doubtful. The author was not able to capture any specimens of moths under arc lights near infested vineyards during the first and second weeks of August in 1915.

During August of 1914 and 1915, moths were turned loose in an open field and followed in their flight. A few of the longest flight records are given, the distance being reckoned without taking into account sudden changes of direction of only a few feet. In reality the actual distance covered on account of the zigzagging flight was often two or three times as far as the record shows.

Moth	Distance (feet)	Moth	Distance (feet)
1	220	57	410
22	308	59	175
36	400	81	106
38	330	95	440
56	600		

A very large percentage of the moths were lost after flying but a few feet, and many more were lost after flying less than 100 feet. Most of the moths traveled with the wind, which was blowing at the rate of not more than one-half to four miles per hour. If the wind was heavy the moths soon settled, generally flying only 20 to 30 feet unless they were let loose at some height, and then they could not be followed with success. There seems to be no reason why they might not be carried several miles by the wind. All these tests were made with recently emerged moths from 2.30 to 5 p. m. At this time of the day the moths are very active.

Variations in extent of injury.—The numbers of the berry worm will often increase for a few years, and then they do almost no injury for a few seasons. This does not seem to be due entirely to parasitism, but is more likely a result of weather conditions. Extreme cold in winter in northern Ohio, with a heavy snowfall, does not seemingly reduce the numbers of living overwintering pupae; but extreme, varying temperatures, with little or no snow or rainfall, will often cause the death of many of the pupae. The injury done to the grape crop varies from a small percentage of infested berries to 95 percent of the crop, and may vary from a slight infestation on one side of the vineyard to more than 80 percent on the other side of the same vineyard. These areas may be less than a mile apart.

EXPERIMENTAL SPRAYING TESTS

EARLY EXPERIMENTS

Various methods of control have been tried. Spraying thoroughly with 3 pounds of arsenate of lead and weak Bordeaux mixture to which 2 pounds of resin soap or 1 pound of dissolved laundry soap had been added (the soap makes the spray stick better and helps to spread around the smooth berries), was in the 1907 and 1908 experiments the most effective remedy. Three applications of spray were usually given: one just before the grapes bloomed; a second when the grape berries were almost as large as peas, or 3 to 5 millimeters in diameter; and a third in July, varying with the season and locality from July 5 to 20. Burning all the leaves and trash early in the fall was thought to be of assistance in controlling the berry worm, but later experiments prove this practice is of little value.

Results at Kelley's Island in 1907.—Tables I, II, III and IV give the kind of treatment, number of sprays, type of application, and results for the experiments in 1907. The final counts for the season

TABLE I.—Tests in spraying against the grape-berry worm (Kelley's Island—1907)

Poison and sticker used	Number of sprays	Type of application	Number of bunches	Number of berries		Harvest for 240 feet of row	Percent wormy
				Wormy	Sound		
						Pounds	
Paris green, soap	Two	Single machine	81	819	2,272	285½	26.50
Arsenate of lead, soap	Two	Single machine	74	655	2,543	315	20.44
Arsenite of soda, soap	Two	Single machine	82	863	2,458	514	26.00
Paris green, soap	Two	Double machine	78	339	2,770	375	10.80
Arsenate of lead, soap	Two	Double machine	75	150	2,963	351¼	4.80
Arsenite of soda, soap	Two	Double machine	71	358	2,722	551¾	11.60
Arsenate of lead, iron sulphate	Two	Double machine	87	850	2,867	378	22.91
Arsenate of lead, no sticker	Two	Double machine	81	621	2,549	400½	19.59
Arsenate of lead, soap	Three	Single machine	77	518	2,768	417½	15.75
Arsenate of lead, soap	Three	Hand	86	71	2,249	550½	3.00
Arsenate of lead, soap	Three	Double machine	73	237	2,742	494½	7.90
Arsenate of lead, iron sulphate	Three	Double machine	72	341	3,008	543	10.18
Arsenate of lead, no sticker	Three	Double machine	86	329	3,508	514	8.57
Arsenate of lead, resin soap	Three	Double machine	91	167	3,554	551½	4.47
Arsenate of lead, resin, sal soda	Three	Double machine	79	135	3,437	479	3.78
Arsenate of lead, soap, resin, sal soda	Three	Double machine	79	247	2,719	366	8.32
Arsenate of lead, soap	One	Hand	86	97	3,291	170 (160 ft. row)	2.90
.....	None	.....	..	2,250	1,605	54½ (160 ft. row)	58.37
Arsenate of lead, resin soap	Two	.....	93	861	2,717	.....	24.06
Arsenate of lead, sal soda, resin	.....	.....	75	730	2,606	.....	21.88

were half-bushel samples picked at random from each of the sprayed plots. The total crop from a definite length of row of each plot was weighed. A decided variation in yield per acre was noted. These experiments were conducted by Prof. H. A. Gossard and assistants at Kelley's Island.

TABLE II.—Comparison of results with different numbers of sprays with arsenate of lead and Bordeaux

Number of sprays	Sticker	Type of application	Percent wormy
None	None	.....	58.37
One (mid-July)	Soap	Hand	2.90
Two	Soap	Double machine	4.80
Three	None	Double machine	7.90
Three	Soap	Hand	3.00

TABLE III.—Comparison of results with single and double sprayings with different poisons with Bordeaux and soap

Type of application	Number of sprays	Poison	Percent wormy
Single machine	Two	Paris green	26.50
Double machine	Two	Paris green	10.80
Single machine	Two	Arsenite of soda	26.00
Double machine	Two	Arsenite of soda	11.60
Single machine	Two	Arsenate of lead	20.44
Double machine	Two	Arsenate of lead	4.80
Single machine	Three	Arsenate of lead	15.75
Double machine	Three	Arsenate of lead	7.90

TABLE IV.—Comparison of results with different stickers with Bordeaux and arsenate of lead (three sprays)

Sticker	Type of application	Percent wormy
Soap	Double machine	7.90
Iron sulphate	Double machine	10.18
None	Double machine	8.57
Resin, soap	Double machine	4.47
Resin, sal soda	Double machine	3.78
Resin, sal soda, soap	Double machine	8.32
Soap	Hand	2.90

Results at Euclid in 1908.—In 1908 the experimental plots were located at Euclid, Ohio. A program similar to the 1907 work at Kelley's Island was followed, the results being given in Tables V, VI, VII and VIII.

TABLE V.—Tests in spraying against the grape-berry worm
(Euclid, Ohio—1908)

Plot	First spraying, June 2–6	Second spraying, June 16–20	Third spraying, July 8–18	Type of application	Percent wormy	Number of bunches in sample	Number of wormy berries	Number of sound berries
1	Bordeaux	Bordeaux	Bordeaux					
2	Arsenate of lead and Bordeaux	Arsenate of lead and Bordeaux	Arsenate of lead and Bordeaux	Double machine	20.88	29	328	1,195
3	Bordeaux	Arsenate of lead and Bordeaux	Arsenate of lead and Bordeaux	Double machine	17.37	24	247	1,175
4	Bordeaux	Bordeaux	Arsenate of lead and Bordeaux	Double machine	12.43	29	185	1,303
5	Arsenate of lead and Bordeaux	Arsenate of lead and Bordeaux	Arsenate of lead and Bordeaux	Double machine	10.72	26	143	1,240
6	Bordeaux	Arsenate of lead and Bordeaux	Arsenate of lead and Bordeaux	Hand	10.76	28	157	1,301
7	Bordeaux	Bordeaux	Arsenate of lead and Bordeaux	Hand	10.03	25	164	1,418
8	Arsenate of lead, Bordeaux and iron sulphate	Arsenate of lead, Bordeaux and iron sulphate	Arsenate of lead, Bordeaux and iron sulphate	Hand	11.95	26	182	1,341
9	Arsenate of lead, Bordeaux and soap	Arsenate of lead, Bordeaux and soap	Arsenate of lead, Bordeaux and soap	Double machine	4.67	25	72	1 469
10	Bordeaux and soap	Arsenate of lead, Bordeaux and soap	Arsenate of lead, Bordeaux and soap	Double machine	2.02	26	30	1 456
11	Bordeaux and soap	Arsenate of lead, Bordeaux and soap	Arsenate of lead, Bordeaux and soap	Double machine	1.86	28	29	1,529
12	Arsenate of lead, Bordeaux and soap	Arsenate of lead, Bordeaux and soap	Arsenate of lead, Bordeaux and soap	Double machiue	.71	29	11	1 528
13	Bordeaux	Arsenate of lead, Bordeaux, and soap	Arsenate of lead, Bordeaux and soap	Hand	1.37	30	21	1 511
14	Bordeaux	Bordeaux	Arsenate of lead, Bordeaux and soap	Hand	1.87	28	28	1 466
	Check				47.43	25	692	767

TABLE VI.—Comparison of results with a different number of sprays with arsenate of lead, Bordeaux and soap

Number of sprays	Type of application	Percent wormy
One	Double machine	1.86
Two	Double machine	2.02
Three	Double machine	4.67
One	Hand	1.87
Two	Hand	1.37
Three	Hand	.71

TABLE VII.—Comparison of results with different stickers with arsenate of lead and Bordeaux

Sticker	Number of sprays	Type of application	Percent wormy
None	One	Double machine	21.43
Soap	One	Double machine	1.86
None	Two	Double machine	17.37
Soap	Two	Double machine	2.02
None	Three	Double machine	20.88
Iron sulphate	Three	Double machine	11.95
Iron sulphate	Three	Hand	4.67

TABLE VIII.—Comparison of results with machine and hand spraying (three sprays with arsenate of lead, Bordeaux and sticker indicated)

Type of application	Sticker	Percent wormy
Double machine	None	20.88
Hand	None	10.72
Double machine	Iron sulphate	11.95
Double machine	Soap	4.67
Hand	Soap	.71

Results at Wooster in 1909.—In 1909 a small vineyard at Wooster was sprayed with dilute lime-sulphur (1 in 50) and arsenate of lead, and the results were compared with those secured where arsenate of lead, Bordeaux and soap were used. The arsenate of lead, lime-sulphur mixture defoliated the grapes and practically destroyed the crop.

In the 1907, 1908 and 1909 experiments, the arsenate of lead paste was used at the rate of 3 pounds to 50 gallons of water or of Bordeaux and sticker mixture. In 1907, Paris green at one-third of a pound to 50 gallons and arsenite of soda at 1 quart to 50 gallons were tested. These poisons are now rarely used in grape spraying.

The 1907 and 1908 spraying results have appeared all the more remarkable to the author since making the life history studies of 1913-15. The three sprayings were made before the first-brood larvae were more than half to two-thirds grown, and the third spraying in mid-July certainly retained but little of its poisonous

effect by the 12th to the 15th of August. This means that nearly all the good results obtained were the direct outcome of the destruction of the early brood of worms which are not mature until the latter part of July.

The grape-berry worm control work was discontinued for three years due to the partial disappearance of the berry worm.

EXPERIMENTS AT EUCLID IN 1913

In the fall of 1912 grape growers in the East Cleveland district appealed to the Ohio Agricultural Experiment Station for help, as the berry worm had almost destroyed their crop. A similar appeal came from the West Cleveland district in 1913.

In 1913 experimental work for the control of the grape-berry worm was begun in the vineyard of Dr. C. C. Arms at Euclid, Ohio. The spring was cold and the grapes were slow in starting. Experimental work was based on previous experience and on the work of Johnson and Hammer at North East, Pa. (see U. S. Dept. Agr., Bur. Ent. Bul. 116, Part II), and a program was planned accordingly. Life history studies had been started the previous fall, as control measures depended largely on knowing the habits of *P. viteana* in northern Ohio.

The set of bunches before bloom was not heavy, promising only a fair crop of grapes for 1913. Plots were selected and a spraying was made before the grapes bloomed. The plots selected were located on almost level land, and each consisted of about two-thirds of an acre of grapes. The larger part of this section consisted of Concords, but the plots included some Catawbas and Delawares and a few Niagaras. A series of different sprays was used, the poison being applied at different strengths, with and without Bordeaux (3-4-50 and 4-4-50) and also with and without soap, and with Bordeaux and soap in order to compare the effectiveness of the poison in different combinations. The various plots were sprayed just before the grapes bloomed, June 9 to 12, shortly after the grapes bloomed, June 18 to 21, and again on July 18 to 21. No moths had appeared at the last date, but it was thought best not to depart too radically from previous experimental work in which good results had been obtained. In the hand-sprayed plots the first and second sprayings were omitted to test the value of one thorough spraying later in the season.

The bulk of the brood of moths coming almost 3 weeks after the third spraying, together with the final results showing serious injury by the grape-berry worm throughout the vineyard, indicated

that the final spraying should be made some 2 or 3 weeks later than had been previously recommended, in order to destroy the second brood of worms, which begin hatching from the eggs about mid-August.

In these experiments the spray was applied with a large-capacity power machine furnishing 200 pounds pressure. The spars were of the fixed type, but differed from the spars of the usual kind in that the nozles were not pointed at right angles to the row of grapevines. They were placed so that the lowest nozzle was about 18 inches from the ground, and were angled so that the spray was thrown upward and outward as well as forward and backward, meeting the leaves edgewise instead of throwing the spray directly against the rooflike protecting surface of the leaves. These special spars were designed by the author, in order to cover completely the bunches of grapes with spray in a thorough manner, approaching, if possible, the best hand spraying in covering capacity. The ability to cover a considerable area of vineyard rapidly with a minimum expense for labor was also an important item, as directing the spray nozzles by hand adds to the cost of spraying grapes. These spars with the nozzles angled outward and upward saved the labor cost of the two men required to direct the nozzles in hand spraying. Where the vines were of normal size, spraying with these spars covered the grapes with spray, but the spray did not always reach all the grape berries where the vine growth in mid-July was extremely heavy. Arsenate of lead paste was used in varying amounts and in combinations with Bordeaux, soap or flour paste. The results are given in Table IX with data concerning the treatment of the plots.

In the 1913 experiments heavy applications of spray were made. One hundred thirty-five gallons covered an acre in the early spraying before bloom, with an increase of 145 gallons for the second treatment, and about 200 gallons for the third treatment made on the 15th to the 18th of July. A sample of the paste arsenate of lead used was analyzed by the Station chemists in order to remove any doubt concerning its poisoning quality. The analysis is given below:

	Percent
Water	42.84
Lead oxide (PbO)	40.05
Arsenic pentoxide (As_2O_5)	14.82
Undetermined	2.29

TABLE IX.—Tests in spraying against the grape-berry worm (Euclid, Ohio—1913)

Plot	First spraying, June 9-12			Second spraying June 18-21			Third spraying, July 15-18			Percent wormy, Sept. 10-11
	Arsenate of lead	Bordeaux	Sticker	Arsenate of lead	Bordeaux	Sticker	Arsenate of lead	Bordeaux	Sticker	
	Pounds			Pounds			Pounds			
1	3	2-3-50	Hard soap 1 lb.	3	2-3-50	Hard soap 1 lb.	4	2-3-50	Hard soap 1 lb.	26.7
2	3	3-4-50	.....	3	3-4-50	.....	4	3-4-50	.....	33.1
3	4	4-4-50	Hard soap 1 lb.	4	4-4-50	Hard soap 1 lb.	6	4-4-50	Hard soap 1 lb.	19.4
4	3	.....	Hard soap 1 lb.	3	.....	Hard soap 1 lb.	4	.....	Hard soap 1 lb.	45.7
5	3	3-4-50	Flour in paste 4 lb.	3	3-4-50	Flour in paste 4 lb.	3	3-4-50	Flour in paste 4 lb.	26.4
6	3	3-4-50	Hard soap 1 lb.	3	3-4-50	Hard soap 1 lb.	3	3-4-50	Hard soap 1 lb.	24.4
Unsprayed.....										84.0

Since the arsenate of lead was of standard strength, and as the same lot was used throughout the experiments, the variance in results must be ascribed to stickers and spreaders or an increased amount of poison. Plots 2 and 4, Table IX, showed a greater percentage of wormy grapes than any of the others excepting the unsprayed plot. In Plot 2 the soap sticker was omitted, and in Plot 4 the Bordeaux was not used. Plot 1 had a much smaller percentage of wormy berries when Bordeaux and soap were used with the same amounts of arsenate of lead. Plots 1, 5 and 6 show but little difference in the percentage of wormy berries with no particular advantage when soap was used as a sticker instead of flour paste. The cost of these materials is very different: One pound of soap costs from 2 to 4 cents and 4 pounds of flour, from 12 to 16 cents. The preparation of good flour paste is a difficult task when compared with the dissolving of soft or cheap laundry soap; hence, the latter is better for general use. The increased amount of arsenate of lead used in the spraying of Plot 3, when compared with Plots 6 and 1, shows an advantage of 5 percent to 7 percent in favor of the greater amounts of poison, especially in the last, or third, spraying. In 1913 most of the brood of berry moths appeared between the 3d and 12th of August, and a thorough spraying between these dates would have undoubtedly destroyed most of the August brood of worms. The 1914 and 1915 experiments have verified this supposition.

EXPERIMENTS IN 1914

The experimental work of 1914 for berry-worm control was more extensive than in previous years, as arrangements were made with the members of the Dover Fruit Growers' Association to cooperate with the Department of Entomology of the Ohio Agricultural Experiment Station, and the experimental work at Euclid, Ohio, was also continued.

Results at Euclid.—In the plot work at Euclid, arsenate of lead was used at the rates of 2 pounds and 3 pounds of the dry, or powdered, material to each 50 gallons of spray. This arsenate of lead did not mix well and was so heavy that the turbine agitator did not keep it all in suspension even when 3 and 4 pounds of soap was used to each 50 gallons of spray. These amounts of poison were used with soft soap, and with Bordeaux and cheap molasses as stickers, or spreaders. Hand spraying was also tested in comparison with machine work. Forty percent nicotine sulphate was used on some plots in the third spraying to test its possible value for the destruction of berry-moth pupae on the leaves and also for the destruction of the leaf hoppers, *T. comes,* and *T. tricincta,* which were extremely numerous on the leaves of part of the vineyard. The results of the experiments at Euclid are listed in Table X.

TABLE X.—Tests in spraying against the grape-berry worm
(Euclid, Ohio—1914)

Plot	First spraying, June 8-10			Second spraying, June 24-27			Third spraying, July 29-31			Percent wormy
	Arsenate of lead	Bordeaux	Sticker	Arsenate of lead	Bordeaux	Sticker	Arsenate of lead	Fungicide	Sticker	
	Pounds			Pounds			Pounds			
1	2	2-3-50	Soap 2 lb.	2	2-3-50	Soap 2 lb.	3	Nicotine sulphate 1-1000	Soap 2 lb.	2.14
2	2	.....	.....	2	.....	Soap 2 lb.	3	.....	Soap 2 lb.	7.10
3	2	2-3-50	Molasses 1½ gal.	2	2-3-50	Molasses 1½ gal.	3	.....	Molasses 1½ gal.	10.40
4	2	2-4-50†	Soap 2 lb.	2	2-4-50†	Soap 2 lb.	3	Nicotine sulphate 1-800	Soap 2 lb.	4.49
5	2	.....	Soap 2 lb.	2	2-3-50	Soap 2 lb.	3	Bordeaux 2-3-50	Soap 2 lb.	1.98
6*	2	2-3-50	Soap 2 lb.	2	2-3-50	Soap 2 lb.	3	Bordeaux 2-3-50	Soap 2 lb.	.86
6a	.	.....	.....	2	2-3-50	Soap 2 lb.	3	Bordeaux 2-3-50	Soap 2 lb.	2.10
6b	.	.....	.....	.	.....	.....	3	Bordeaux 2-3-50	Soap 2 lb.	1.43
Unsprayed.....										33.20
Neighboring unsprayed vineyard.....										54.00

*Plots 6, 6a and 6b were hand-sprayed.
†In addition to this, 4 pounds of iron sulphate was used.

In the various plots, arsenate of lead as the poison, gave a wide range of results with the different stickers, or spreaders, and fungicides. Plot 2—arsenate of lead and soap—and Plot 3—arsenate of lead and molasses—gave the highest percentages of wormy grapes of any of the sprayed plots. In Plots 1, 5 and 6, similar results were obtained, but Plot 6b, with only one thorough spraying in the latter part of July, had only 1.43 percent of wormy berries. Plot 6, given three thorough sprayings with the nozzles directed by hand, had less than 1 percent of wormy grapes. On Plot 4 the iron sulphate Bordeaux, used in place of the regular Bordeaux mixture, seemed to be the probable factor which promoted the growth of the grape canes and made them look much thriftier than adjoining plots treated with the regular 2-3-50 Bordeaux. Plot 1, which also received the nicotine spray in the latter part of July, did not have such a strong growth of new wood. A few vines sprayed by hand with arsenate of lead with gelatine as the spreader and sticker had 4.7 percent wormy berries; while Plot 6b, receiving arsenate of lead, Bordeaux and soap, had only 1.43 percent wormy berries. The nicotine spray had apparently no effect on the berry worm at this time, but undoubtedly would be of some benefit if it was applied 9 to 12 days later, or about the 8th to 11th of August.

The cane growth in 1914 was not heavy, so that there was a consequent reduction of foliage. This condition was largely responsible for the machine-sprayed plots being almost as free from worms as the hand-sprayed plots.

Plots 6, 6a and 6b had three, two and one spray, respectively, applied by hand, the trailer method being used. The one spraying in the latter part of July gave the largest net profit. The sprayings made before and after bloom did not produce a sufficient additional quantity of sound grapes to cover the extra cost of applying them.

The set of grapes in the vineyards at East Cleveland in 1914 was light, with small clusters resulting in the production of a crop below the average in quantity.

The grape-berry worm seems always to injure a light crop of grapes much more than it does a heavy crop. The first brood of worms, especially, destroys many of the young berries and sometimes the entire cluster. The worms of the second brood are fully as plentiful as when the crop of grapes is normal with often no more than half to two-thirds as many berries for the brood to attack. In such seasons many grape growers do not have sufficient sound grapes in their vineyards to pay for picking them.

Results at Dover.—In the Dover region similar results were obtained as at Euclid when instructions were followed and the sprayings were carefully done. These results are given in Table XI.

TABLE XI.—Tests in spraying against the grape-berry worm (North Dover, Ohio—1914)

Vineyard	Date of spraying with mixture indicated			Percent wormy
	Arsenate of lead 3 lb. paste, Bordeaux 2-3-50, soap (soft) 2 lb.	Arsenate of lead 4 lb. paste, Bordeaux 2-3-50, soap (soft) 2 lb.	Arsenate of lead 4 lb., water 50 gal., syrup 1½ gal.	
1*	June 8-11	June 22-26	July 23-30†	3-7
2*	June 8-11	June 22-26	July 23-30	2-5
3*	June 8-11	June 22-26	July 23-30	1-4
4	June 8-11	June 22-26	July 23-30	1-2.5
5	.....	July 8-15	.....	8-11
6	.....	July 8-15	.....	10-21
7	.....	.....	July 22-31	3-22
8	Unsprayed	.....	.....	None
9	.....	.....	July 23-30	6-10
10	Unsprayed	.....	.....	3-11
11	.....	.....	About July 10	14-37
	Unsprayed (check)	.....	.....	31-68

*Sprayed with power machines; No. 1 was hand-sprayed in some sections, July 23-30.
†Bordeaux 2-3-50 was also used.

In these experiments each cooperator did all the spraying in his vineyards, the author only giving directions regarding the time of spraying and the material to use. The sprayings were made with whatever type of machine the cooperator could afford to purchase or the machine he already owned. In some cases the applications were made at times when they were of little value, and other cooperators used inadequate and inefficient machines. The table shows the value of proper spraying, as some of the cooperators who obtained the best results had the worst infestations of berry worm to fight.

Some striking results were often noted side by side, among them being the extremes of worminess; from full foliage to no foliage on Delawares on September 23, where the 2-3-50 Bordeaux with arsenate of lead had held the downy mildew in check, while arsenate of lead used alone had failed to do so and the fruit on the defoliated section did not ripen well. A few examples of vineyard sprayings with 4-4-50 Bordeaux were near other vineyards sprayed with 2-3-50 Bordeaux. The shorter cane growth and the reduced amount of foliage caused by the former spray were very noticeable, especially where it was used both before and after bloom, with the arsenate of lead and soap. The opposite condition in iron sulphate sprayed sections was fully as noticeable, the 2-3-50 Bordeaux sprayed plots being considered normal.

In the experiments at North Dover in 1914 a shrinking of the berries and a dying of the stems toward the tips of the bunches were noted in Ives grapes. The syrup sticker appeared to be responsible when it was used in combination with arsenate of lead, but this could not be definitely determined, as some Ives grapes were found which were similarly affected but had been sprayed with arsenate of lead and Bordeaux mixture, and in one case they had not been sprayed at all. A sample of the arsenate of lead used was sent to S. K. Johnson, state inspector of insecticides, whose report of analysis is appended:

	Percent
Arsenic oxide	17.72
Soluble oxide	0.27
Lead oxide	58.50
Water	19.80

The sample had evidently become dried out but the small amount of soluble arsenic oxide could not be responsible for the injury caused. Other varieties of grapes were not injured; Concord and Delaware vines were not affected when in the same rows as the Ives.

EXPERIMENTS IN 1915

The results obtained in 1913 and in 1914 left little doubt that the spray before bloom and the one 5 to 8 days after blooming were not of as much value as the August spraying in controlling the berry worm. In 1915 the spraying before bloom was omitted entirely except in a few badly infested vineyards. Some vineyards received only one thorough spraying in August with 3 pounds of powdered arsenate of lead in combination with 2-3-50 Bordeaux and 2 pounds of soft soap. Arsenate of lead in dry and paste forms was the only poison used in combination with Bordeaux and the various stickers in the 1915 experiments at Euclid.

The experiments for the control of the grape-berry worm in 1915 were more extensive than in the years just preceding. The work was conducted in several different grape-growing districts in northern Ohio in order to ascertain the practical value of the previous experimental work. Whenever the cooperators followed instructions and made the heavy application of spray from the 3d to the 12th of August carefully and thoroughly, good results were obtained, averaging less than 15 percent wormy berries in heavy infestations where unsprayed vineyards had 28 to 97 percent wormy grapes. The various cooperators who sprayed at other times, not following instructions, only confirmed the striking results

obtained by spraying at the proper time. A large number of such instances have been carefully observed, although not all this spraying was done by cooperators in the berry-worm control work.

TABLE XII.—Tests in spraying against the grape-berry worm (Euclid, Ohio—1915)

Plot	First spraying, June 29—July 2			Second spraying, August 4—7			Percent wormy, Sept. 20
	Arsenate of lead	Sticker	Bordeaux	Arsenate of lead	Sticker	Bordeaux	
	Pounds	Pounds		Pounds	Pounds		
1	6 Paste	Soft soap 2	2-3-50	6 Paste	Soap 2	2-3-50	8.6
2	6 Paste	*Soft soap 2	.....	6 Paste	*Soap 2	.....	14.2
3	.....	.....	.....	3 Dry	*Soap 2	.....	17.4
4	.....	.....	.....	4 Dry	Soap 2	2-3-50	9.0
5	2 Dry	Soap 2	2-3-50	4 Dry	Soap 2	2-3-50	10.6
6	2 Dry	Soap 2	2-3-50	2 Dry	Soap 2	2-3-50	17.7
7	2 Dry	Soap 2	2-3-50	2 Dry	No soap	2-3-50	30.0
	Check plot unsprayed No. 1						81.2
	Check plot unsprayed No. 2						97.3
	Average unsprayed						89.2

*In 50 gallons of water.

TABLE XIII.—Tests in spraying against the grape-berry worm (Dover, Ohio—1915)

Cooperator	First spraying, June 20–July 9			Second spraying, July 26—August 13	Percent wormy
	Arsenate of lead paste	Soap	Bordeaux		
	Pounds	Pounds			
1	*4	2	2-3-50	No treatment	27
				First spray repeated in late July	†14
2	*4	2	2-3-50	No treatment	15
3	*4	2	2-3-50	Aug. 11–13, paste 6 lb., Soap 2 lb., Bordeaux 2-3-50	11
4	4	2	2-3-50	Aug. 4–7, paste 6 lb., soap 2 lb , Bordeaux 2-3-50	8
5	4	2	2-3-50	.....	57
6	4	2	2-3-50	.....	54
7	No records of spraying work				31
8	No records of spraying work				37
9	No records of spraying work				67
10	Unsprayed				82

*Sprayed with power machines.
†Unsprayed near No. 2, 74 percent wormy.

TABLE XIV.—Tests in spraying against the grape-berry worm (E. L. Steuk's vineyard, Sandusky, Ohio—1915)

Variety	Percent wormy when sprayed*		Percent wormy when unsprayed
	August 8-12	August 15-17	
Worden	3.0	....	46
Catawba	2.0	10.0	89
Concord	2.5	9.0	77

*Arsenate of lead 3 lb. Corona dry; Bordeaux 2-3-50, soft soap 2 lb. applied by hand. Count of wormy berries taken Oct. 7.

CONTROL MEASURES

SPRAYS AND SPRAYING MACHINERY

Time of spraying.—In the grape-berry worm control work the vulnerable spot in the life history appears to be from the time just preceding the depositing of the eggs upon the berries until just after the hatching of the easily poisoned little worms. The moths emerging in June rarely come in a short period of less than a week to 10 days, although in 1914 the bulk of the June brood of moths came in 4 to 5 days (see life history chart). The August brood of moths comes with a rush, almost 90 percent of the pupae transforming into moths in 6 or 7 days. The egg-laying period is also of short duration, and the poison remains effective for the entire period. In 1915 large numbers of moths placed in cages with bunches of grapes sprayed with arsenate of lead died within 2 days, while those confined with unsprayed bunches lived from 4 to 11 days. This is worthy of further investigation, as it may happen only when the moths are in confinement. No eggs were deposited in the first-mentioned cage, but in the latter eggs were plentiful. In the field the first eggs could be found in abundance on the 10th of August, 1914, but could not be readily found in the vicinity of Cleveland until the 14th of August in 1915. On August 15, 1915, they could be readily found at Sandusky, Ohio. West of Cleveland a few unhatched eggs were found on August 24, 1915, but they were not plentiful. A few unhatched eggs were found on the grapes at Sandusky during the first week of September.

In the control work the best results have been obtained by the heavy application of spray, 4 pounds of arsenate of lead paste being used in 50 gallons of Bordeaux with 2 pounds of soft soap, the week following the blooming of the grapes, when the largest berries are about one-eighth inch in diameter. The second application comes between 6 and 7 weeks later, or approximately 7 weeks after the grapes bloom. This late application of spray should be heavy and thorough, covering every bunch of grapes, preferably by the trailer method. Normally, in northern Ohio this spraying comes between the 3d to 12th of August.

From 80 to 200 gallons of spray per acre have been used in the various experiments. For the June spraying 100 to 120 gallons per acre applied with spars was effective, but the August spraying requires about 160 gallons per acre applied by hand. A greater amount of poison, 6 pounds arsenate of lead paste to 50 gallons, should also be used in this spraying. The amount of poison adhering at picking time is undoubtedly small, although considerable

spray may still be visible on the bunches. During the 6 to 9 weeks elapsing between the time of the last application of spray and the time of picking, the poison is almost wholly oxidized or dissolved, and no injurious effects will result from eating these grapes. In most cases the material remaining is lime, as no spray can be seen on grapes sprayed with arsenate of lead and soap. The application of arsenate of lead, Bordeaux and soap made on the same dates had quite a noticeable amount of spray adhering to the berries in some sections of the vineyard, while other sections receiving the same treatment were entirely free from any residue of the late application of spray. The net value of the crop from a sprayed vineyard is also two to five times greater than from an unsprayed vineyard, provided the vineyard is well cared for and thrifty.

Spraying with a traction machine equipped with fixed spars at intervals of about 10 days throughout the season has been tried by some growers. The first application was made before the grapes bloomed, arsenate of lead and Bordeaux mixture being used; and the last application was made about the 15th to 20th of July, the same spray mixture being used for each application. The results were fairly good, although no better than were obtained from three sprayings, one just before bloom, a second when the grape berries are about as large as peas, and a third about the 10th to 15th of July. These recommendations have been tried with the first, and with the first and second treatments omitted, and also with the second, with the third, and with the second and third spraying omitted, with the results always in favor of omitting the first and second treatments but never the third.

Poisons.—Various poisons have been tried at different rates, with arsenate of lead proving the most effective and economical poison to use. As fungicides, Bordeaux of different strengths, lime-sulphur and copperas-Bordeaux have been thoroughly tested. Lime-sulphur and its combinations have always injured the grapes seriously wherever used. The 2-3-50 Bordeaux has given excellent results as a fungicide, besides acting as a sticker and giving body to the spray mixture. Copperas and lime has also proved effective as a fungicide and sticker, but this is a disagreeable mixture to apply.

Stickers.—As spreaders and stickers, copperas, resin soap, fish oil soap, cheap molasses, glucose, flour paste, gelatin, cheap laundry soap and soft soap have been tested in various combinations with poison and with poison and fungicides. Soft soap is the most practical material, as it is easily prepared for use, is inexpensive

and is the most effective spreader and sticker when used with arsenate of lead and 2-3-50 Bordeaux mixture. It also aids in keeping the arsenate of lead in suspension in the tank of the sprayer, preventing uneveness of mixture.

Machines.—In the berry-worm control work many kinds of sprayers were used. The barrel and platform pumps were satisfactory when the spraying was done by hand, care being taken to cover the grapes thoroughly with spray. These pumps do not have sufficient capacity to supply four or more good nozzles or spars. Traction sprayers which utilize power transmitted from the wheels have sufficient capacity to supply four or six small nozzles at 60 to 120 pounds pressure. The pressure soon decreases if the nozzles are not shut off as soon as the horses are stopped or when turning. Most of the traction machines are unsatisfactory when the trailer method of applying the spray is used. Where the grape grower has from 8 to 35 acres of vineyard, a narrow-truck power sprayer with a 100- or 150-gallon tank is the most efficient and convenient machine. A well-designed machine of this type equipped with a jet or siphon tank filler should be about 7 to 7½ feet long, exclusive of the tongue. The regulation width wagon truck is too wide for vineyard spraying. The trucks 8 inches to a foot narrower were more readily handled in turning without catching on posts and brace wires at the ends of the vineyard. The spars with the nozzles throwing the spray upward and outward were very good for the June spraying when the foliage and cane growth was not extremely heavy and when the spray would reach the grape bunches. Their use also depends upon the system of training the grape vines, as they cannot be used at all with some systems.

For the August spraying the trailer method, in which the spray is applied by hand, is more effective and economical, as it is not always possible to cover every grape bunch with spray by means of fixed spars at this season of the year. In 1914 the spar method proved almost as satisfactory as hand applications, but the wood growth was not heavy. In 1915 the wood growth was extremely heavy, and hand spraying proved much better than when fixed spars were used. These spars are attached at the rear end of the machine. Their width and height can be regulated. This enables the spray to be placed on the grapes without saturating the driver or team all the time while the spray is being applied.

Get a good spraying machine of ample capacity—purchasing a sprayer because it is cheap is false economy. The best-equipped

machine obtainable is not always troubleproof. A poor one always leaves a bad flavor behind, carying with it a dislike for spraying and a disgusted, discouraged and doubting operator.

Nozzles.—Nozzles are very important accessories in grape spraying. The small-capacity, short-range nozzles are of little value. Nozzles having a carrying capacity or range of 8 to 12 feet at 200 pounds pressure permit the operator to reach every grape bunch without tangling his nozzles with the grape vines. A nozzle throwing a solid cone of spray is preferable, as it covers more effectively than any hollow-cone spray. A 4-foot bamboo covered rod was the most convenient kind to use. These rods were used on leads of hose 40 to 60 feet long, so that the two men who were handling the rods did not get in each other's way.

GOOD HUSBANDRY

Throughout the grape district the poor growth of the vines with only a partial stand of vines is very much in evidence. The vineyards have been cultivated for many years without adding fertility of any sort. These clay soils wash and leach badly, and the continuous clean culture methods practiced have promoted this condition. Cover crops to hold the soil in winter and spring are almost a necessity. Rye is among the best of the cover crops for this purpose and makes a good green manure crop to plow under during the latter part of May and the first week in June. Manure should also be applied liberally every year, as these clay soils need decaying vegetable matter to release their fertility and to help them to retain moisture. The soil in many vineyards becomes so dry and hard within a week after a rain that plowing and cultivating are impossible. One-eighth to one-sixth of the vines on an acre are often dead or missing, which means much wasted effort to care for such land with no monetary returns. Careful training and pruning also prevent the waste of spray material. The vines should cover the trellises as nearly as possible, and varieties having radically different habits of growth should not be put out in mixed plantings.

The upbuilding of the soil, in order to produce a maximum crop protected from berry-worm injury by careful, thorough spraying, will more than treble the present net income of the average acre of grape vineyard. Spraying at the proper times will prevent injury to the crop of grapes in the vineyard, but manure and cover crops must also be used in order to get maximum results in vine growth and crop production, a practice which requires at least 3 years to reach this point.

In some localities the grape vineyards are being set to peach trees and the vineyard torn out a year or two later. An equal amount of effort applied in improving cultural, training and spraying methods involved in growing grapes will produce as large a net income at the end of 10 years, if shipping facilities and markets are equally good. The continuance of present methods of spraying and cultural conditions for another decade will result in the vanishing of a large part of the grape industry in Ohio.

Clean cultivation.—The studies of the life history and control of the grape-berry worm have included a large amount of experimental work. On a fairly large acreage the moist leaves lying on the ground and upon which the berry worm had spun cocoons in the fall were gathered in October and destroyed. This resulted in a material reduction in the numbers of the berry moth the next summer. One owner found he could pick from 1 to 3 acres per day, depending upon the condition of the vineyard. If the vineyard is well cultivated and free from weeds and grass, the work of collecting the leaves is neither difficult nor tedious. Where a cover crop, as rye, is used or when the vineyard is full of weeds, it becomes almost impossible to collect the leaves and the cocoons of the berry worm successfully. The leaves having cocoons upon them must be gathered before the frost causes all the leaves to fall.

Plowing in the latter part of May covers pupae still in the vineyard and assists in reducing the number of moths in June, provided the soil is in good physical condition.

However, these methods must not be relied upon entirely for the control of the grape-berry worm. Picking all the wormy and split-open berries and destroying them has been tried quite often by grape growers in northern Ohio, but without success as a control measure. All the wormy grapes on several small arbors near Wooster were gathered in mid-July by the author. The arbors had to be gone over three times during a period of about a week in order to get, if posible, all the wormy berries. The grapes in these arbors were almost free from worms at picking time, but the work in a vineyard could not be as carefully and thoroughly done at a reasonable cost, and reinfestation would be a certainty within a season's time.

The bunches of grapes, especially in unsprayed sections of a vineyard, often serve as the home for spiders. These bunches are not seriously injured by berry worms, as is shown in Table XV giving the counts of sound and wormy berries in a sample from an unsprayed plot.

TABLE XV.—Sound and wormy grapes in a sample from an unsprayed plot

Sound	Wormy	Sound	Wormy	Sound	Wormy
2	42	"	26	0	30
3	50	5	39	12	27
3	39	0	34	3	33
8	31	4	37	3	54
5	62	10	36	16	29
26*	9	*28	11	0	41
3	31	5	27	5	33
7	40	2	39	3	51
28*	12	*21	20	2	42

The bunches marked with an asterisk were occupied by spiders, and if these are not considered, the number of wormy grapes is increased 7 percent.

FINAL RECOMMENDATION

Spray with arsenate of lead, 4 pounds of paste, 2-3-50 Bordeaux and 2 pounds of soft soap, beginning 7 to 10 days after the grapes start to bloom. The second spraying with 6 pounds of arsenate of lead paste, instead of 4 pounds, should be made about 7 weeks after the grapes bloom or between the 3d and 12th of August in northern Ohio. Exceptional years may necessitate this application being made a few days earlier or later, depending upon the season and whether the grapes bloom earlier or later than the normal date. Put on the second application, or August spray, by the trailer or hand method, using 120 to 160 gallons per acre. Spray thoroughly, covering every bunch of grapes with spray if possible, making the applications as near to the proper time as conditions will permit, and remember that careless work is only wasted effort.

SUMMARY

1. The studies of the life history and devising of measures for the control of the grape-berry worm have extended through several years.

2. Completed life history studies show that the berry moth completes its life cycle twice in a year, or the insect is two brooded.

3. The moths transforming from the overwintering pupae emerge throughout a period of 20 to 30 days in June and July, making the periods during which the eggs hatch of equal duration.

4. Earlier publications have recommended three sprayings: one just before bloom, a second when the grapes are about as large as peas, and a third about July 10 to 15.

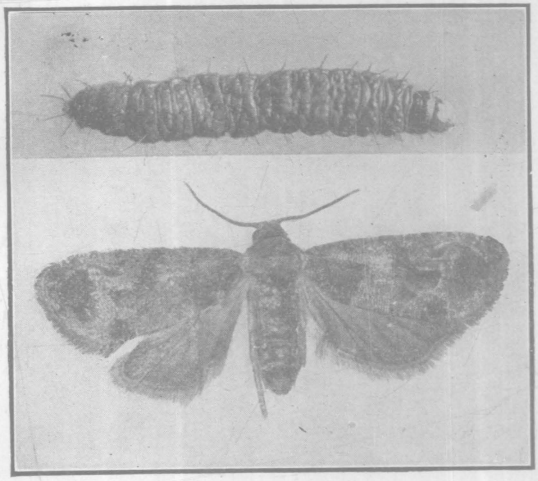
5. The recent and complete life history studies have shown that by following this program the three sprayings for berry-worm control were made before the first-brood larvae were grown. The third spraying from July 10 to 15 was made almost a month before the eggs of the second brood of berry worms for the season were hatched, leaving small probability of sufficient poison adhering at this time to kill many of these newly hatched worms.

6. By timely, thorough spraying, in accordance with the known life history development, the berry worms have been controlled, their injuries being reduced to an almost negligible amount.

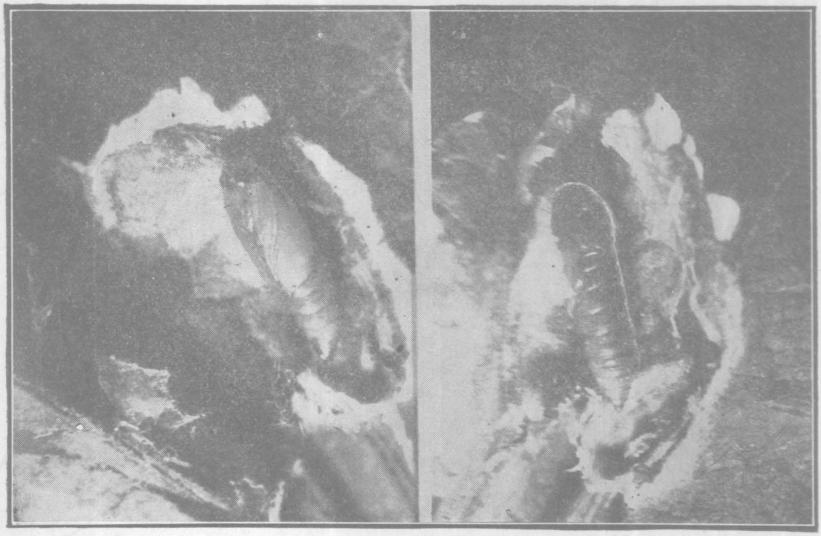
7. These sprayings should be extremely thorough. Arsenate of lead 4 pounds, Bordeaux 2-3-50, and 2 pounds of dissolved soft soap should be used for the first spraying just after the blooming of the grapes, when the largest berries are about one-eighth inch in diameter. This poison spray kills many of the first-brood worms.

8. The second spraying must be made just preceding the placing of the moth eggs on the grape berries and stems of the berries. In normal years the time of this spraying comes between the 3d and 12th of August, depending upon whether the grapes bloom earlier or later than normally or about 7 weeks after the grapes bloom. This time can also be determined by placing a lot of wormy grapes in a jar about the 20th of July with leaves on top of the berries: tie a piece of cloth over the top of the jar and place it outdoors in the shade. Spraying for the control of the second-brood worms must be started about 10 days after the first-brood worms begin to spin cocoons on the grape leaves. Use arsenate of lead paste 6 pounds, Bordeaux 2-3-50, and dissolved soft soap 2 pounds, covering every bunch with spray, applying it preferably by hand.

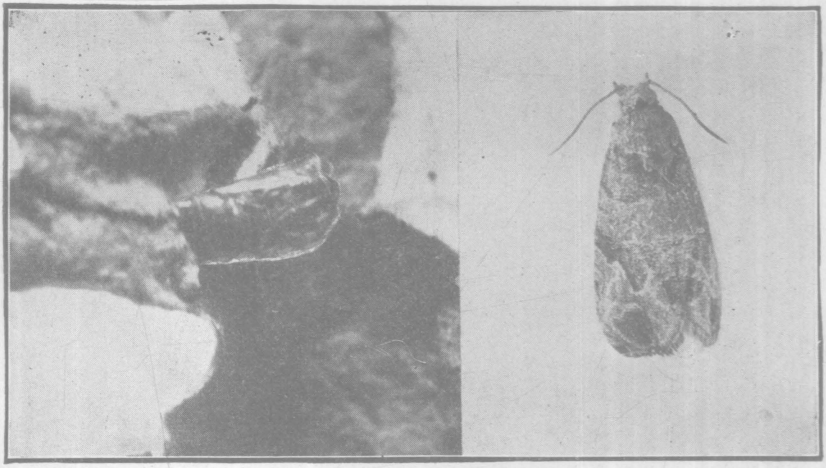
9. Care for the vineyard intelligently; prune it; train it; cultivate it; fertilize it; spray it properly at the right times; and success will be assured.



The grape berry moth { a. Larval stage
b. Adult with spread wings, enlarged 6 diameters

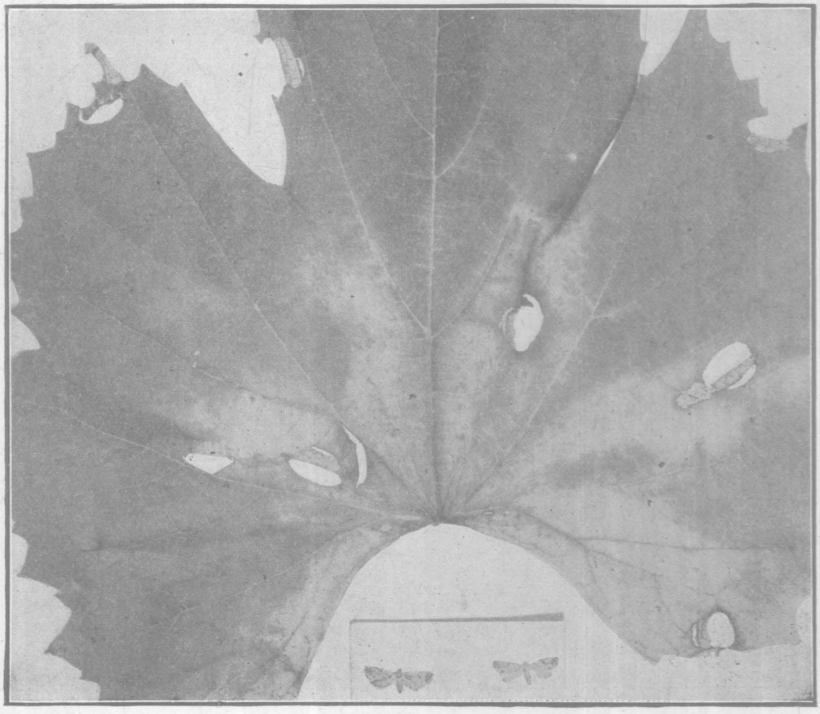


Berry worm, pupal stage, ventral side Berry worm, pupal stage, dorsal side
Enlarged

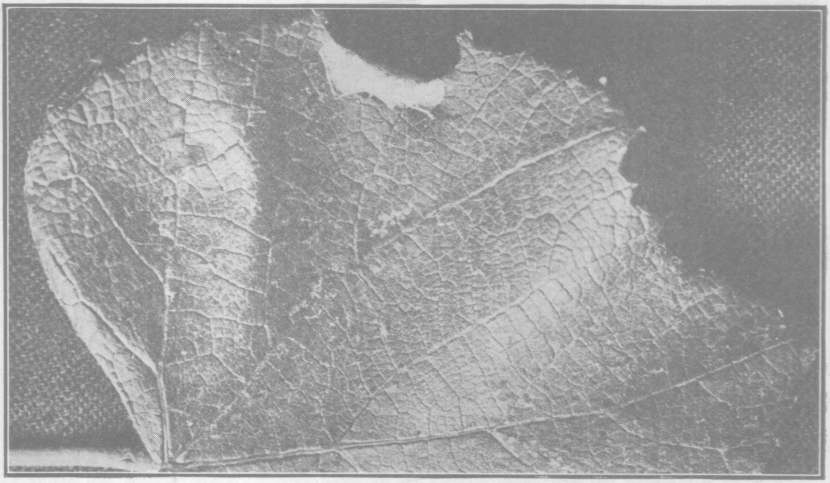


Berry worm, empty chrysalis enlarged

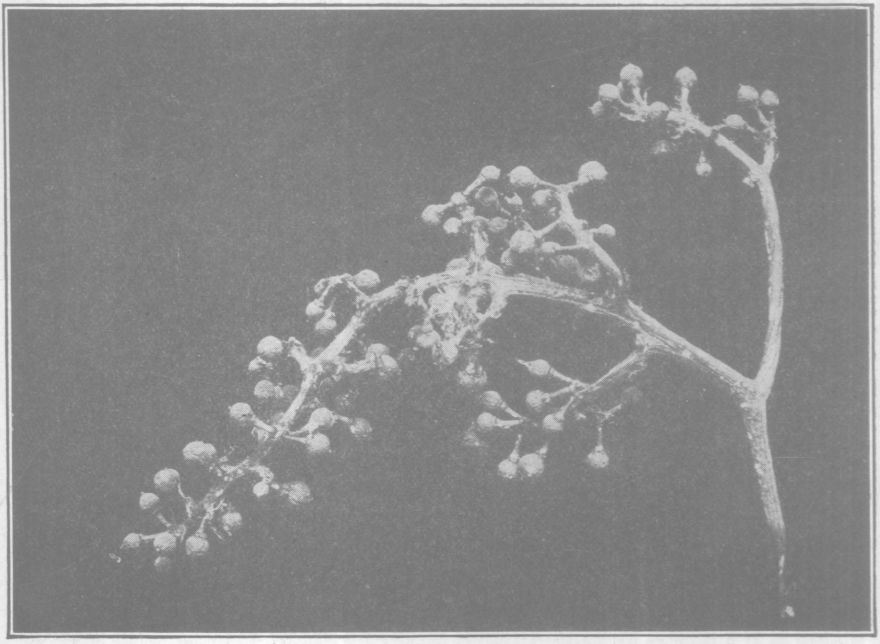
Berry worm moth at rest, enlarged 8 diameters



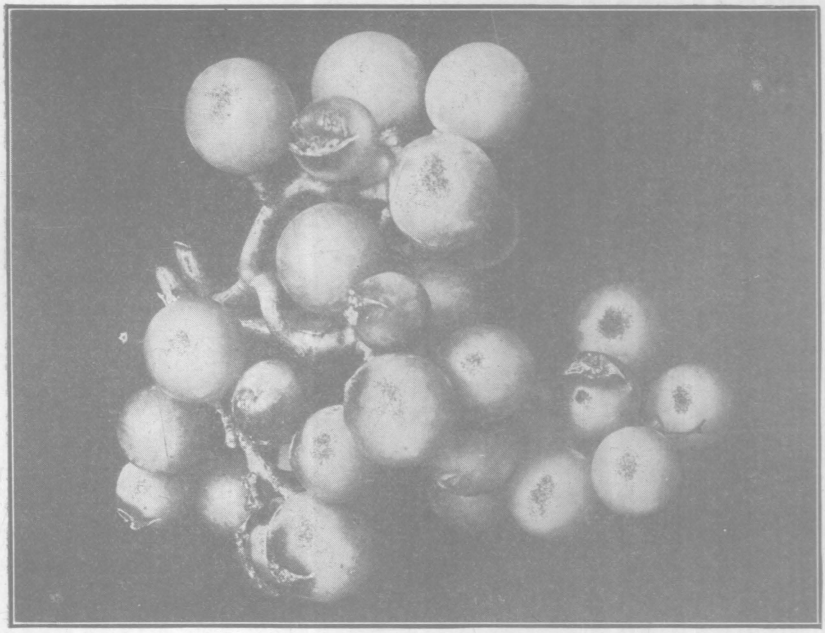
Cocoons on a leaf in October and moths with wings spread, natural size



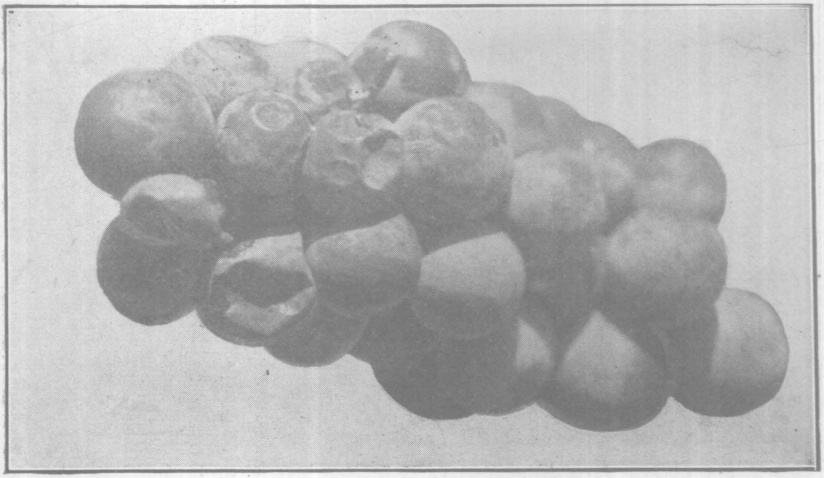
Cocoon on young grape leaf, in the latter part of July



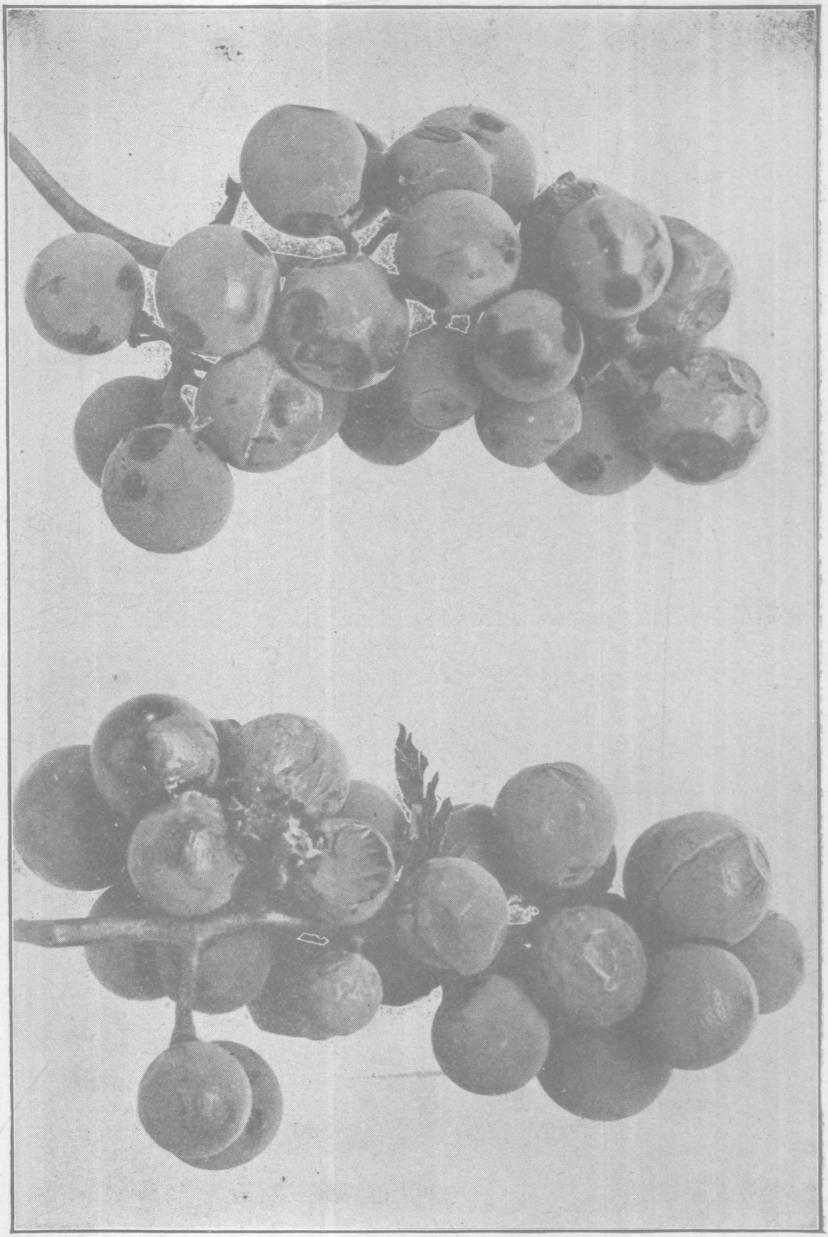
Worms webbing and destroying a young grape cluster



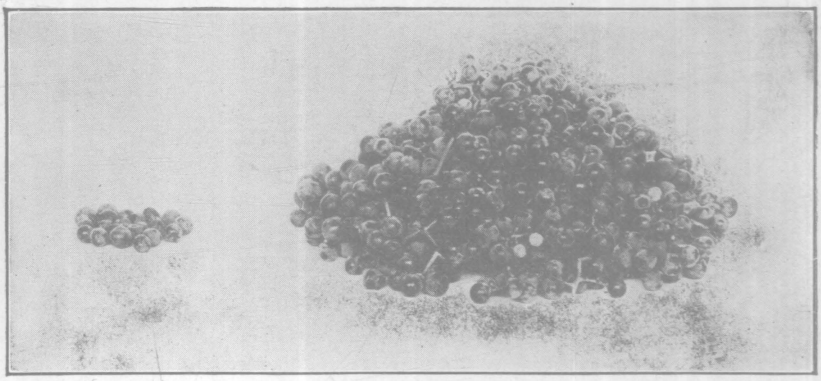
Two small bunches of grapes in mid-July showing the berries attacked by late individuals of the June-July brood of berry worms, split open and with the premature coloring appearing along the edges of the break



A bunch of Concord grapes on the vines in late September. Every berry has been injured by berry worms

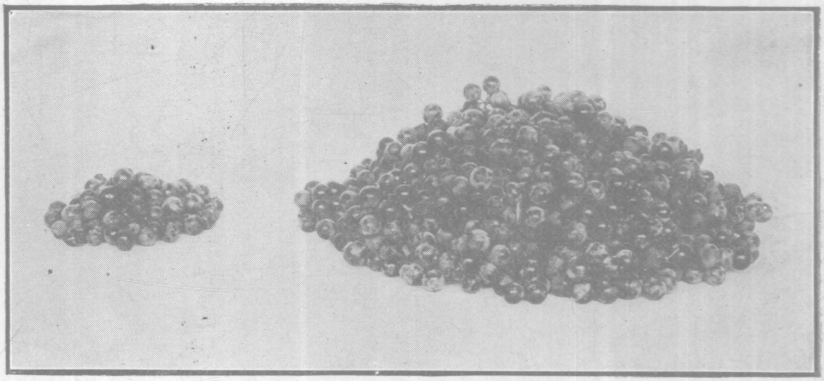


Two bunches of Concords picked from an unsprayed vineyard in late September



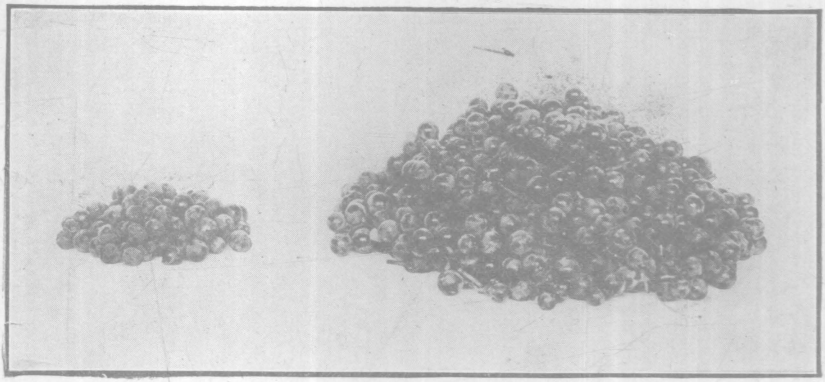
Basket sample from Plot 1, 1914

Sprayed June 9; arsenate of lead 2 lb. powdered, 2-3-50 Bordeaux, soft soap 2 lb.
Sprayed June 24; arsenate of lead 2 lb. powdered, 2-3-50 Bordeaux, soft soap 2 lb.
Sprayed July 30; arsenate of lead 3 lb. powdered, soft soap 2 lb., nicotine sulphate 1 part in 1,000 of spray.
Wormy 2.14 percent



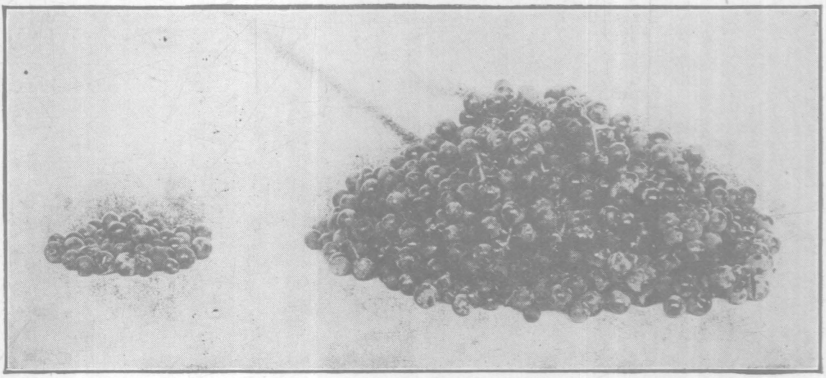
Basket sample from Plot 2, 1914

Sprayed June 9; arsenate of lead 2 lb., soap 2 lb., water 50 gal.
Sprayed June 24; arsenate of lead 2 lb., soap 2 lb., water 50 gal.
Sprayed July 30; arsenate of lead 3 lb., soap 2 lb., water 50 gal.
Wormy 7.1 percent



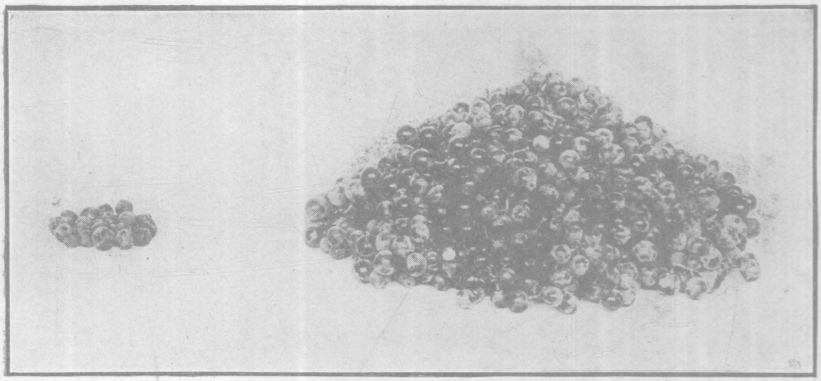
Basket sample from Plot 3, 1914

Sprayed June 10; arsenate of lead 2 lb., Bordeaux 2-3-50, molasses 1½ gal.
Sprayed June 26; arsenate of lead 2 lb., Bordeaux 2-3-50, molasses 1½ gal.
Sprayed July 30; arsenate of lead 3 lb., molasses 1½ gal.
Wormy 10.4 percent



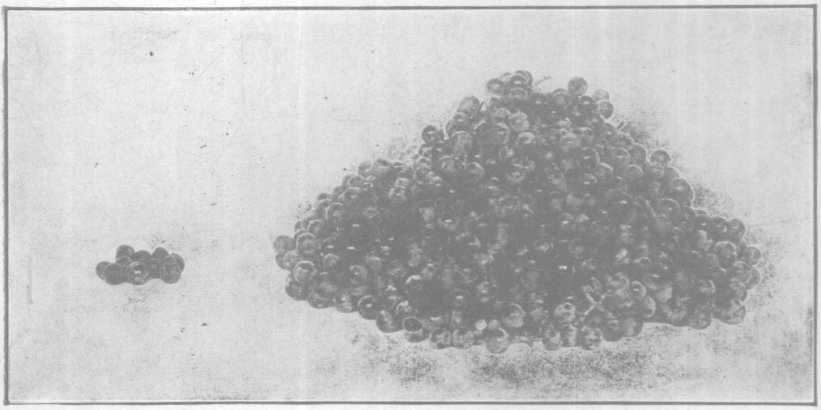
Basket sample from Plot 4, 1914

Sprayed June 10; arsenate of lead 2 lb., copperas 4 lb., lime 4 lb., soft soap 2 lb.
Sprayed June 24; arsenate of lead 2 lb., copperas 4 lb., lime 4 lb., soft soap 2 lb.
Sprayed July 29; arsenate of lead 2 lb., soft soap 2 lb., nicotine 1 in 800
Wormy 4. 49 percent



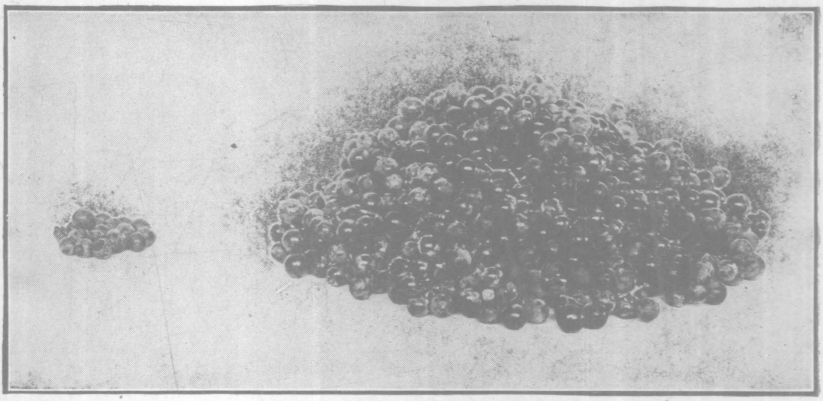
Basket sample from Plot 5, 1914

Sprayed June 10; arsenate of lead 2 lb., Bordeaux 2-3-50, soft soap 2 lb.
Sprayed June 25; arsenate of lead 2 lb., Bordeaux 2-3-50, soft soap 2 lb.
Sprayed July 29; arsenate of lead 3 lb., Bordeaux 2-3-50, soft soap 2 lb.
Wormy 1.98 percent

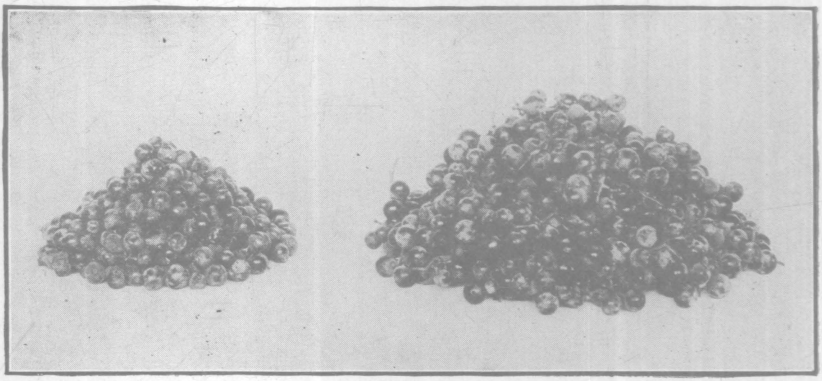


Basket sample from Plot 6, 1914

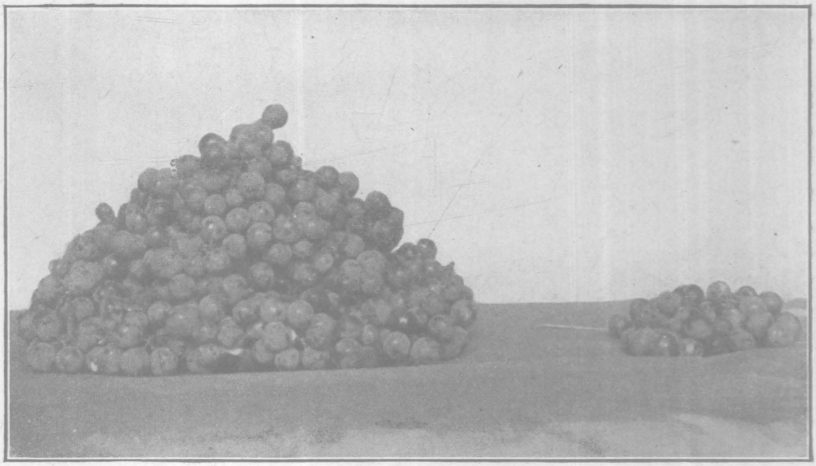
Hand sprayed on same dates as Plot 5 with the same sprays. Wormy .86 percent



Basket sample from Plot 6b, 1914
Hand sprayed with the same spray as used in Plot 5 on July 29. Wormy 1.43 percent



Basket sample from check plot
No spray. Wormy 33.2 percent

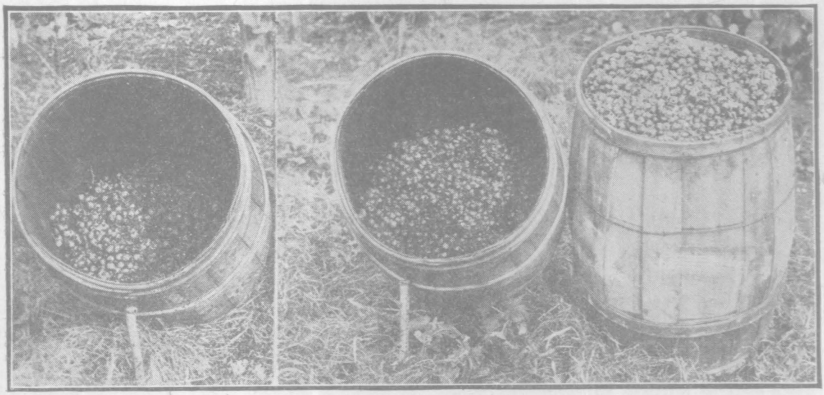


Basket sample from Plot 1, 1915

Sprayed June 29; arsenate of lead paste 6 lb., Bordeaux 2-3-50, soft soap 2 lb.
Sprayed August 6; arsenate of lead paste 6 lb., Bordeaux 2-3-50, soft soap 2 lb.
Wormy 8.6 percent

Basket sample from check plot, 1915

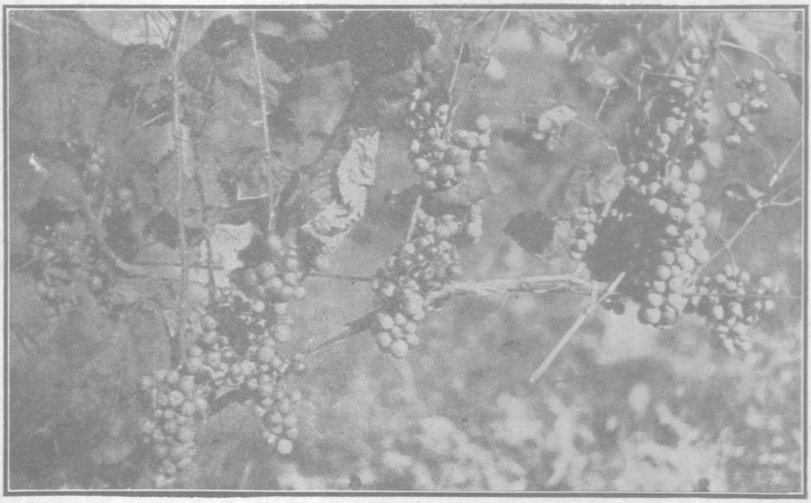
Unsprayed. Wormy 81.2 percent



Crop from 160 feet of unsprayed row, 1907

Crop from 160 feet of row sprayed once, 1907

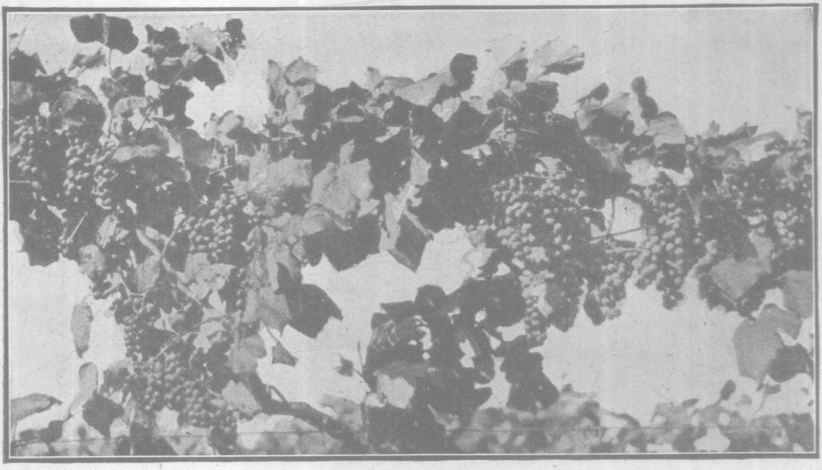
Catawba grapes



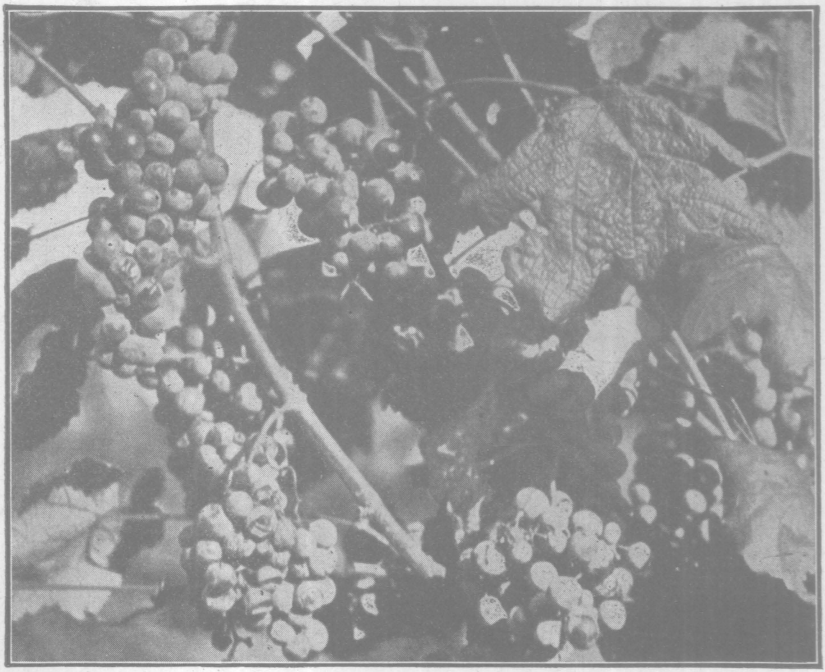
Unsprayed Catawba grapes, 1915

Catawba grapes sprayed with Derror tree fluid

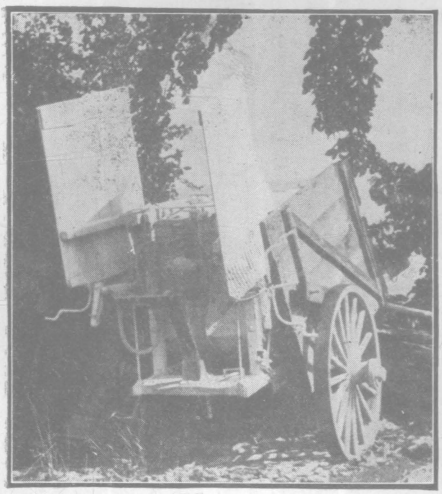
Catawba grapes sprayed with arsenate of lead, Bordeaux and soap



Catabwas sprayed with arsenate of lead, Bordeaux and soap



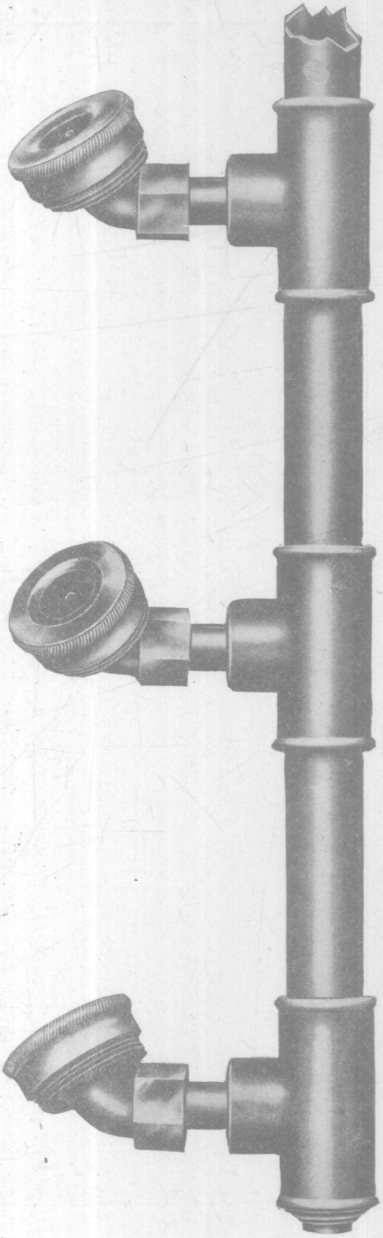
Unsprayed Concords



Traction sprayer with straight spars placed almost three feet from the ground

Small traction sprayer directing the nozzles by hand

Power sprayer equipped with spars and in operation



Detail of spar used on power sprayer
shown on page 301

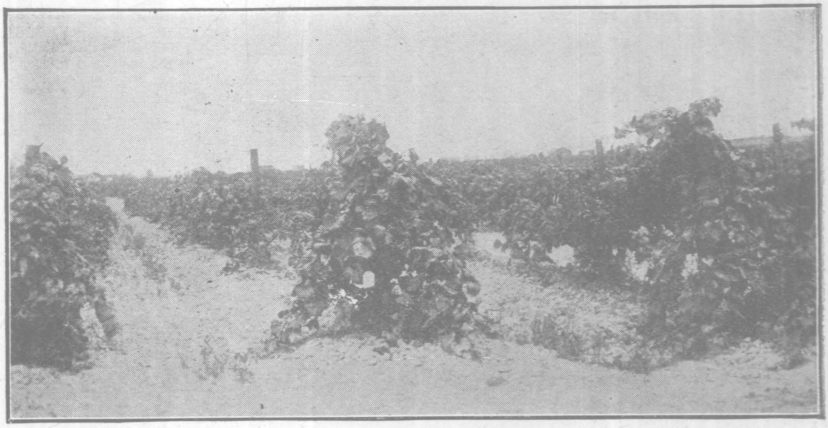
Spray on Worden grapes

A clean vineyard

Abandoned vineyard in July. Even the weeds make poor growth

Vineyard thrift

Abandoned vineyard in March at the end of the slope where the wash is caught by grass and weeds. This is more fertile than the vineyard shown on page 304.

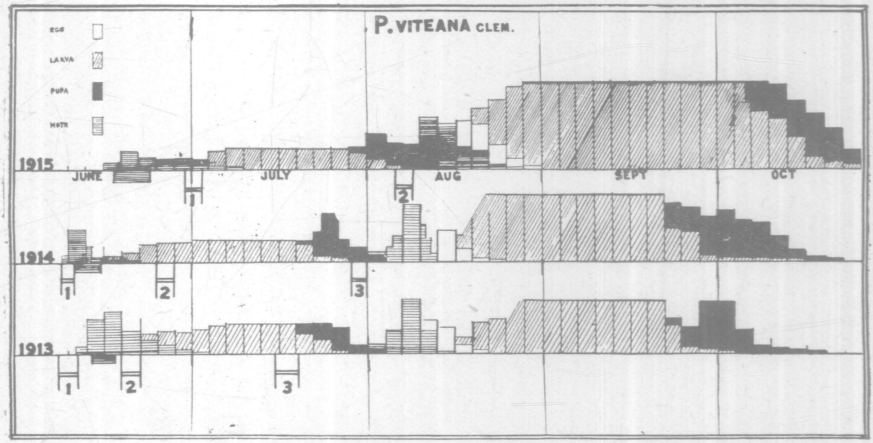


Cultivated but not tied or tucked. This method is supposed to create conditions not liked by the berry worm, but this vineyard had over 90 percent of the berries wormy.

Pruned, cultivated and trained, but without the addition of manure or fertilizer

Vineyard view. Many vines missing. See also figure shown on bottom of page 305 and figure ahown above

The change. Peaches displacing grape vineyard



Life history chart for 1913, 1914 and 1915

In 1913 the records given are breeding cage records only up to the first week in July. Cage records after that time are supplemented with very careful field observations and records. The figures below the life history records give the times the applications of spray were made. Each division above the base lines represents a three-day period. Under the lines in June the darkened area shows the duration of the blooming period of the standard varieties of grapes. The stages of the insect, duration of the stages and their abundance are pictured graphically for the three seasons in the shaded portions above the lines. The figures 1, 2 and 3 below the base lines show when the applications of spray were made in the vineyard at Euclid, Ohio, but do not include the spraying work at North Dover and Sandusky, Ohio. In each year's work results show that the August spraying should be made about ten days after the first brood worms begin to spin cocoons.